

## **Remote Microscopy: The Virtual Laboratory Concept**

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### **Introduction**

The Materials Analysis User Center (MAUC) in the High Temperature Materials Laboratory (HTML) at Oak Ridge National Laboratory is currently developing new research collaborations in a variety of materials research areas. Historically, one of the major goals of our laboratory is to make unique research facilities available to industrial and academic users, to improve American competitiveness and to develop the next generation of engineers and scientists. The HTML User Program has been particularly successful over the last decade in developing collaborations in the area of materials research, with over 125 industrial and 120 university legal agreements currently in place. Another metric of the extent of our interactions is the number of user days: over 4000 industrial and 2000 academic user days in FY 1995 (an average of 15 visiting researchers are present **every** day of the year). Recently our activities have expanded to include research not related to high temperature materials. We have begun to use our instrumentation and expertise to make nationally significant contributions in several new areas including light weight materials and emission catalysts.

### **Digital and Remote Microscopy**

The Materials Analysis User Center incorporates five advanced scanning and transmission electron microscopes, a surface analysis instrument, an electron microprobe and scanning probe instruments. This gives us the capability to image individual rows of atoms in crystal structures, determine elemental compositions of these rows, determine elemental composition of a layer of atoms on a surface, or to determine composition of particles as small as 10 nm. Over the last three years, we have modified our instruments with the addition of digital camera systems and digitally controlled scanning capabilities, so that now each one of them is operable directly from a standard computer local to the instrument. All images and spectra are collected on the computer in digital format, and are stored on large memory devices or written to CD-ROM for archive purposes. This computer control capability coupled with the high demand for instrument time and an increasing level of outside research activity has encouraged us to explore the concept of TelePresence microscopy and remote operation of our instruments.

Over the past several years we have pursued vigorously the remote microscopy concept and have made advances such that we lead the nation in this area. We have demonstrated that we can operate our most sophisticated transmission and scanning electron microscopes from any place in the country. We illustrate our current capability in the poster figures. One instrument that can now be operated remotely is the Hitachi HF-2000 field emission gun transmission electron microscope. This instrument is one of the most advanced electron microscopes in the world, and costs about \$1.6M as

presently equipped. It is also one of the most difficult instruments to control from an external computer, because transmission electron microscopy typically requires a large number of precise adjustments and alignments by the operator for proper development of the image. In turn, enabling these adjustments from a computer requires a large number of programming steps. Via a scripting language, a large number of programs for computer control have been successfully integrated into the software provided by the manufacturer of the digital camera we use to record images from the microscope. We can now control all of the microscope lenses and deflectors from a standard Macintosh computer, and have automated some of these functions to further facilitate operation of the microscope. As an example, an operator would usually have to make changes in the illuminating beam every time the magnification was changed, so that the image would remain at a roughly constant brightness. Under computer control, the brightness is automatically controlled as magnification is changed, which simplifies the operation.

### **The User Interface**

One important aspect of our implementation of remote microscopy is the user or client interface. All that is required is an inexpensive commercially available program from Farallon called Timbuktu Pro, which allows the remote computer to mirror the operation of the local computer. Thus the remote operator sees on his computer screen the identical program being run on the local computer, and can in fact run that program to collect images in the same way the local operator runs the program. He or she can see the digital images as they are collected locally, and these images can be transferred to his remote computer as final, full resolution images using the network connection. The same remote presence can be generated using web page tools such hypertext markup language (html, not to be confused with the High Temperature Materials Laboratory—HTML) and associated subprograms. Either method of client remote operation can be done from a PC (Macintosh, DEC) platform for under \$500 for initial hardware and software, and, using standard digital telephone service (ISDN) to provide assured bandwidth. ISDN service is now available throughout most of the country for less than \$50 per month communications cost.

The details of remote control of our microscopes, hardware and software, and consequences for our user programs are presented on the poster. Using a desk top computer and a digital telephone line, the Hitachi HF-2000 in the HTML will be remotely operated from the lobby of the Ritz Carlton in Dearborn.